CSIRO PyroPage

Putting science into practice

www.csiro.au

Number 26 | **February 2020**

Thermal interactions of merging lines of fire

The behaviour of high intensity wildfires is often characterised by multiple individual fires, such as spot fires, interacting and merging in a variety of configurations. A recent study in the CSIRO Pyrotron investigated the heat transfer interactions of two lines of fire intersecting at a range of angles. It was found that in dry eucalypt litter the presence of wind is required for any thermal interaction effect to be observable. This effect can double the rate of spread expected in two merging fires if there was no interaction.

Fire coalescence and merging firelines

A key characteristic of the behaviour of short-lived high intensity wildfire events in many fuels is profuse and dense spotting from firebrands and embers downwind of the main fire. The presence of these new ignitions leads to an increase in the overall spread rate of a bushfire and enables the fire to traverse gaps in fuel and breaks in topography. Coalescence or the merging of mass spot fires, particularly when the spread of the main fire is held up, can result in the formation of 'pseudo' fire fronts (McArthur 1967), large segments of spreading fire disconnected from the main fire producing zones of discontiguous burning where areas within the outer perimeter of the fire do not burn sequentially.

Understanding the potential for spot fires to merge and form propagating fronts is essential to understanding the likelihood of wildfires developing erratic behaviour that will unexpectedly increase intensity and could potentially lead to entrapments. Figure 1 illustrates the three main forms of fireline interactions generally found in coalescing spot fires: (A) fire lines intersecting at oblique angles; (B) non-intersecting fire edges propagating towards each other; and (C) collapsing or constricting perimeters that form a pseudo-ring that propagates towards the centre. These heat transfer or thermal interactions, comprised of both convective and radiative components from the flames, may be oriented at any angle to the direction of the prevailing wind.

For spot fires developing a short distance downwind of a large main fire, the local wind at the surface may be modified significantly by blocking of the prevailing wind by the plume of the main fire. Here winds may be greatly reduced in speed and have directions different (even contrary) to that prevailing outside the fire area.

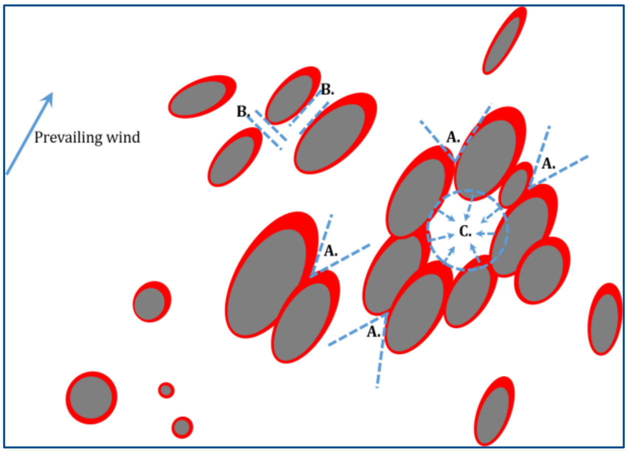

Figure 1. Examples of fire line interactions (dashed lines) of coalescing spot fires include: (A) intersecting oblique lines; (B) non-intersecting converging fire edges; and (C) collapsing or constricting perimeters. These may be oriented at any angle to the prevailing wind.

Experimental investigation

Little research has been done on this topic, particularly in real fuels. Viegas et al. (2012) studying 'V'-shaped fires in beds of straw with no wind found that there was a strong thermal interaction as the 'arms' of the 'V' merged as measured by an increase in the rate of spread of the vertex of the 'V', R_v, when compared to the speed of a single line of fire in isolation, R_0 (Fig. 2).

The current work is the first to investigate interactions of intersecting 'V'-shaped lines of fire in both the absence of wind (i.e. calm) and presence of wind (~1.0 m/s) in real bushfire fuels, namely dry eucalypt forest litter. If no interaction occurs between the two 'arms' of the V, then any change in the speed of the vertex is due solely to the geometry of the arrangement, the 'geometry' effect.

Experimentation took place in the CSIRO Pyrotron combustion wind tunnel utilising the surface litter from a local forest. Fuel beds of 1.2 kg/m^2 were conditioned to a moisture content of between 3 and 6% oven-dry weight, representative of long-unburnt fuels under wildfire conditions. Four incident intersection angles (15, 30, 45 and 60°) were studied using two symmetrical ignition line lengths: 800 and 1500 mm (Fig. 2). With four replicates for each set of conditions, a total of 40 experiments were conducted using the 800-mm ignition length (20 no wind and 20 with wind) and 24 using the 1500-mm ignition length (12 no wind and 12 with wind).

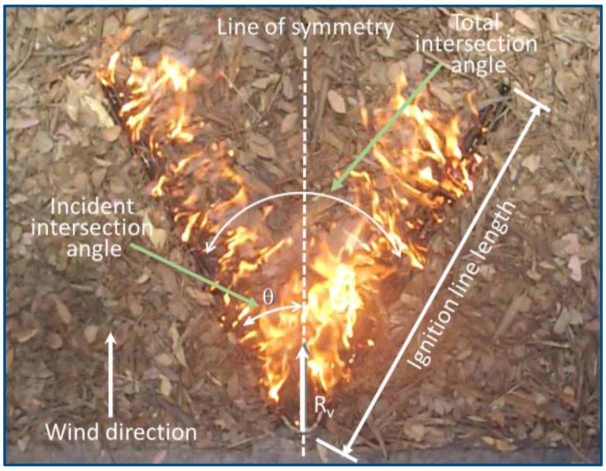

Figure 2. Annotated video frame from an experimental 'V' fire with an 800 mm ignition line at a 30° incident angle 20 seconds after ignition. The rate of spread of the vertex, R_v, relative to the geometry effect on the rate of spread of a single fire line, is the measure of thermal interaction of the two arms of the 'V'.

The rate of vertex spread, R_v, for each experiment was measured digitally from rectified and scaled planar video images taken from the Pyrotron ceiling (Fig. 2). These values were normalised against the rate of spread of a single line of fire, R_0, for each incident angle. Normalised R_v values were then compared with the geometry effect to determine if any thermal interaction had occurred.

Results

Figure 4 summarises the results of the study, contrasted with those found in straw without wind and the geometry effect. In the absence of wind, no effect beyond that of the geometry was observed in forest litter, unlike in straw.

In the presence of wind, however, a strong effect of thermal interaction on R_v was observed at acute angles, almost twice that expected if there was no interaction. However, this effect rapidly weakened beyond an angle of 45° to less than 20% faster at an incident angle of 60°.

Ignition line length at this scale in the presence of wind only made a minor significant difference, with the longer line spreading slightly faster.

A generally weak heat transfer interaction effect was observed at all incident angles outside the arms of the 'V' where flames were observed to lean toward the centre of the 'V', limiting outward propagation of the fire (Fig. 2).

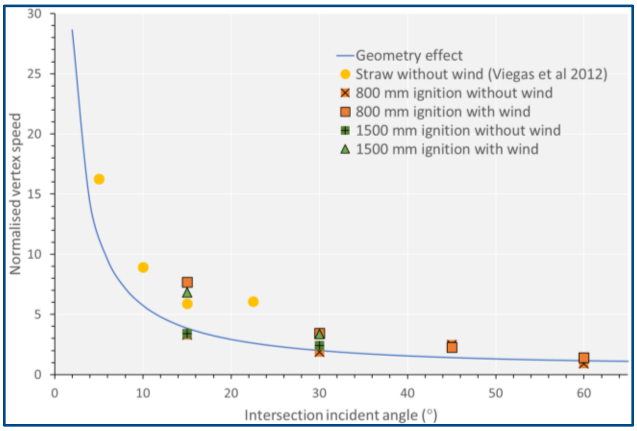

Figure 4. Graph of normalised vertex speed and intersection incident angle showing that only those experiments with wind had any significant thermal interaction.

Conclusion

Convective and radiative interactions from merging lines of fire can result in speeds twice as fast as would be expected if there were no thermal interactions. These interactions appear to depend on the bulk density of the fuel and the presence of wind. Larger fires burning with higher heat release rates in a wind are likely to interact over greater distances, affecting their behaviour. Further research is required to determine the factors and scales that influence this behaviour.

Further reading

Sullivan AL, Swedosh W, Hurley RJ, Sharples JJ, Hilton JE (2019) Investigation of the effects of interactions of intersecting oblique fire lines with and without wind in a combustion wind tunnel. International Journal of Wildland Fire 28, 704–719. doi:10.1071/WF18217.

References

McArthur AG (1967) Fire Behaviour in Eucalypt Forests. Forestry and Timber Bureau Leaflet 107, Commonwealth Department of National Development (Canberra).

Viegas DX, Raposo JR, Davim DA, Rossa CG (2012) Study of the jump fire produced by the interaction of two oblique fire fronts. Part 1. Analytical model and validation with no-slope laboratory experiments. *International Journal of Wildland Fire* 21, 843–856.

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

FOR FURTHER INFORMATION

CSIRO Land and Water
Dr Andrew Sullivan
t +61 2 6246 4051
e Andrew.Sullivan@csiro.au
w www.csiro.au/en/Research/LWF

An archive of this and previous CSIRO PyroPages is available from: http://research.csiro.au/pyropage